Disease Control and Pest Management

Incidence of Aphid-Transmitted Virus Infections Reduced by Whitewash Sprays on Plants

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ABSTRACT

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Weekly sprays of potato crops with 15% whitewashes of Loven and Yalbin reduced potato leaf roll virus (PLRV) incidence in tubers from 0–61% of the level in the untreated plots in seven independent experiments. Similar sprays with 2% Virol oil, did not reduce PLRV in three experiments. Loven and Yalbin sprays reduced potato virus Y (PVY) incidence in potato to 0–68% of the level in controls, which is roughly comparable to the reduction obtained with Virol oil (0–52%). Whitewash sprays were less efficient for PLRV and PVY control than coarse, white net covers. Weekly sprays with whitewash reduced total tuber yield by about 30%, about the same yield decrease caused by oil treatment in our conditions. However, the number and weight of tubers between 30 and 120 g (seed size) in whitewash-treated plots was not affected. Two effects could explain the activity of whitewash. The whitewashes increased leaf reflectivity in the visible spectrum by 130–250%, whereas oil treatment caused no change. This change in reflectivity agrees with the reduced number (30–50%) of aphids landing in whitewash-treated plots, whereas no reduction in aphid landing occurred in Virol treatments. However, different aphid species responded differently; for example *Aphis gossypii* was attracted to whitewash-treated plots. In our experiments, whitewash and oil treatments did not affect PLRV acquisition by aphids. Loven and Yalbin plus a sticking agent Dabak reduced PLRV inoculation by aphids, although Virol plus Dabak and Dabak itself had no effect compared with untreated plots.

Additional key words: pepper.

Mulching crops with a reflective surface like aluminum foil or white or gray plastic reduces the number of aphids landing and virus incidence (8,10,11,17,19,20). Aluminum foil mulch was found to be more effective than white or gray plastic (10,11), presumably because of its higher reflectivity. This method seems to reduce virus incidence effectively, but is not widely practiced, mainly because of its high cost and the fact that crops shade or cover the mulch, limiting the repellency effect to a rather short, early period (21). A more recent development aimed at overcoming this problem is to cover crops with white, reflective, coarse nets. This method was found to decrease aphids and the incidence of both nonpersistent (6,7) and persistent (7,13) viruses. The coarse net is not a barrier for aphids but rather repels their landing, presumably because of its high reflectivity (6). The high cost of materials and labor are the main disadvantage of the above-mentioned methods, and, therefore, their use has been limited to small plots of high-value crops. The objective of the present work was to investigate the possibility of reducing virus incidence by applying whitewashes of reflective materials directly onto plants.

MATERIALS AND METHODS

Field experiments were carried out in potato research plots during spring, summer, and autumn over several years. Potato plots were cultivated similarly to commercial fields and the treatments (three to six replications) were distributed at random. The spring experiments of 1984 and 1985 were carried out in commercial potato plots on the Golan Heights. Each replication consisted of three rows of different lengths, with the middle row serving for measurements. The reflective materials used were whitewashes of Loven (Tapazol Co., Rishon LeZiyon, Israel), which contains inert reflective materials and 6% Zn, and Yalbin (Tapazol), which contains 2.5% Zn and inert reflective materials, among them Ca (3). Dabak (0.2%) (consisting of 40% polyvinyl and 60% inert material; Tapazol Co.) was added to solutions of the whitewash (10–15%) to increase stickiness and sprayed by a SOLO knapsack hand sprayer type 425 equipped with a T.j. 8004 nozzle. These sprays increased potato leaf reflectivity throughout the

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visible spectrum wavelengths by 130–250% (Fig. 1), as measured by a Bausch & Lomb spectrophotometer (Spectronic 20) with a reflectance attachment. Virol (Pazchim, Co., Tel Aviv, Israel), which consists of 80% medium light oil and 20% water and emulsifiers, was sprayed similarly to the whitewashes, but at a concentration of about 2%. Because all experiments were carried out in overhead irrigated plots, the solutions were sprayed onto the plants once a week (the day after irrigation), starting from about 50% emergence. Protection by net cover was previously described by Marco (13); net tunnels were stretched on flexible plastic sticks to a height of 90 cm in the center.

Virus. From the middle row of each replication a medium-sized tuber was sampled at random from each plant. The tubers were artificially sprouted by Rindite treatment (9). PLRV was assayed until 1979 by the sprout test (12): aphid transmission from apical sprouts to the indicator plants *Datura stramonium* L. and/or *Physalis floridana* Rydb. Starting in 1980, PVY and PLRV were assayed by direct, double antibody sandwich enzyme-linked immunosorbent assay (ELISA), as described previously (14). Dilutions of PVY antiserum were 1:1,000 for coating and 1:500 for conjugate and dilutions of PLRV were coating 1:1,500 and conjugate, 1:1,000. Apical sprouts were homogenized in PBS-Tween (1:5) with no additives. Because the tests were done at least in duplicates, not all the sprouts could be assayed for both PLRV and PVY.

Aphids. Winged (alate) aphid populations were estimated by using yellow sticky traps and yellow water traps (9). The sticky traps consisted of rigid, yellow plastic cards (20 × 14 cm) sprayed with a sticky transparent glue (Rimifoot, Jewnin & Joffe, Tel Aviv, Israel) mounted horizontally on stands and adjusted to about crop height. The cards were changed every 1–3 days, and the number of trapped alatae was counted.

The water traps were yellow plastic pans (30 × 35 cm) about half-full with water, to which about 10 ml of Dimanin A (33.3% alkyl dimethyl benzyl ammonium chloride; Chimgat Lidor, Co., Ramat HaSharon, Israel) was added to prevent development of bacteria and algae. Pan height was also adjusted to the haulm height, and once a week the trapped aphids were collected, divided into groups (*Myzus persicae* Sulz. and all other aphids), and counted.

Wingless (apterae) aphid populations were estimated in the potato experimental plots by counting the total number found on 10 randomly chosen plants approximately 1 wk before harvest.

Landing of different aphid species on Loven-treated and control plots was assessed in pepper plots during the spring of 1981. The experiment included six replications, each of which consisted of two 1-m^2 plots (15 plants), spaced 2 m apart. One of the plots was sprayed with Loven at about 5% (higher concentrations damage young pepper seedlings) and the other was unsprayed. In each plot a water trap was located and the traps were handled as above, except that, in this case, all trapped aphids were prepared for microscope examination according to Bodenheimer and Swirski (5) and identified under the guidance of Dr. J. F. Eastop (British Museum, London).

The possible interference of the presence of whitewash materials on the leaves with the PLRV acquisition by aphids was determined as follows. Undetached leaves of PLRV-infected potatoes from our laboratory were smeared by a hair brush over half their surface with the tested materials plus 0.2% Dabak, whereas the opposite (control) half-leaf was smeared with Dabak 0.2% only. On each half-leaf, virus-free *M. persicae* apterae from the culture source were placed in leaf cages and allowed a 24–48-hr acquisition period. Subsequently, two aphids were transferred onto young *D. stramonium* seedlings for an inoculation period of 48 hr. Then the seedlings were sprayed with pirimicarb (0.05% Pirimor 50WP) and maintained in an insect-proof greenhouse for symptom development; the incidence (percentage) of infection as detected by ELISA, was compared in treated and control groups.

The possible interference of Loven with PLRV inoculation also was examined. Aphids that acquired virus from infected potato in the same leaf cage were allowed (two aphids per plant) to inoculate indicator seedlings that were dipped in or sprayed with the tested materials. Seedlings treated similarly with water (untreated) served as the controls. The plants were handled thereafter as described above.

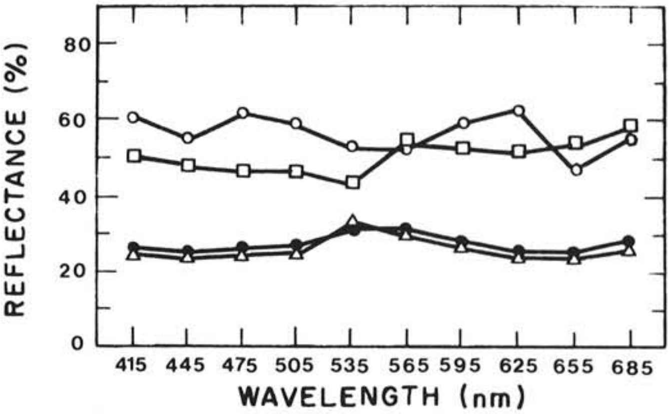

Fig. 1. Reflectivity (% reflectance of white porcelain) of the upper side of a potato leaf following a spray with: 15% Loven plus 0.2% Dabak (o—o); 15% Yalbin plus 0.2% Dabak (□—□); 2% Virol 0.2% Dabak (Δ—Δ); and 0.2% Dabak (•—•).

TABLE 1. Percentage of potato leaf roll virus infection in potato tuber populations from plots treated with Loven, Yalbin, Virol, or covered with white, coarse net, compared with untreated controls[w]

Treatment	1978[x] 3[y]	1979 6	1980 3	1980 4	1981 5	1982 6	1984 4	Total
Control	13.3 (30) a	7.3 (247) a	10.0 (80) a	16.4 (181) a	3.0 (136) a	4.1 (197) a	2.8 (182) a	7.4 (1,053) a
Loven	3.2 (30) a	1.0 (197) a	0.0 (29) b	7.8 (423) bc	0.9 (227) a	1.4 (208) a	1.7 (410) b	3.1 (1,524) b
% Protection[z]	76	86	100	52	70	66	39	
Yalbin				5.4 (322) c	0.0 (182) a	1.0 (201) a		2.7 (705) b
% Protection				67	100	76		
Virol				12.2 (115) ab	2.5 (120) a	3.2 (186) a		5.5 (421) a
% Protection				26	17	22		
Coarse net				0.0 (92) d		0.0 (110) b		0 (202) c
% Protection				100		100		

[w] Data with the same letter not significantly different as analyzed by Duncan's multiple range test for $P \leq 0.05$. In parentheses: Number of samples assayed by double sandwich ELISA except for 1978 and 1979 when the sprout test (13) was used.
[x] Year.
[y] Number of replications.
[z] $\% \text{ Protection} = 100 - \frac{(\text{infection in treated} \times 100}{\text{infection in control})}$.

TABLE 2. Percentage of potato virus Y infection in potato tuber populations from plots treated with Loven, Yalbin, Virol, or covered with white, coarse net, compared with untreated controls[w]

Treatment	1980[x] 4[y]	1981 5	1982 6	1984 4	Total
Control	1.9 (106) a	2.2 (90) a	3.1 (98) a	2.2 (182) a	2.3 (476) a
Loven	0.8 (118) a	0.0 (68) b	2.1 (94) a	1.2 (427) a	1.1 (707) b
% Protection[z]	58	100	32	45	
Yalbin	0.0 (120) a	0.0 (96) b	0.9 (115) a		0.3 (331) bc
% Protection	100	100	71		
Virol	0.0 (95) a	0.0 (62) b	1.6 (64) a		0.5 (221) bc
% Protection	100	100	48		
Coarse net	0.0 (71) a	...	0.0 (104) b		0.0 (175) c
% Protection	100	...	100		

[w] Data with the same letter are not significantly different as analyzed by Duncan's multiple range test for $P \leqslant 0.05$.
[x] Year.
[y] Number of replications.
[z] $*\%\ \text{Protection} = 100 - \frac{(\%\ \text{infection in treated} \times 100}{\%\ \text{infection in control})}$.

TABLE 3. Yield parameters of potato tubers from plots treated by reflective whitewash, oil, a combination of the two, and untreated control[z]

Parameter	Loven	Yalbin	Virol	Loven Virol	Yalbin Virol	Control
Number of tubers (30 g)	28	31	29	32	27	37
Number of tubers (30–120 g)	105	101	79	90	79	86
Number of tubers (120 g)	20 c	35 b	33 b	6 d	13 cd	55 a
Total numbers of tubers	153	167	141	128	119	178
Weight of tubers (30 g)	1,910	2,040	1,970	2,090	1,790	2,780
Weight of tubers (30–120 g)	7,352	6,783	5,898	5,530	5,568	6,103
Weight of tubers (120 g)	3,375 cd	4,933 bc	5,748 b	995 e	2,025 de	11,245 a
Total yield (g)	11,205 b	12,226 b	12,139 b	7,048 c	8,021 c	18,043 a

[z] Data with the same letter not significantly different as analyzed by Q-test for $p < 0.05$. Results are means of four replications from the middle row of three 5-m long rows.

Statistics. Yields were analyzed by the Q-test, the arc sine of infection percentages by Duncan's multiple range test, whereas results related to alatae trappings and apterae development were analyzed by the Mann–Whitney U-test (16) for $p \leqslant 0.05$.

RESULTS

Effect of sprays with Loven, Yalbin, and Virol on PLRV and PVY incidence. In seven experiments over 6 yr in different seasons and areas, Loven treatments reduced PLRV incidence in potato tubers to 24, 14, 0, 48, 30, 34, and 61% of the incidence found in the control plots ($p < 0.05$) (Table 1). In three independent experiments, Yalbin treatments reduced PLRV incidence to 33, 0, and 24% of that found in the control plots ($p < 0.05$), whereas oil treatment was not significantly different from the control. Net cover conferred absolute protection (Table 1).

In four experiments, Loven sprays reduced PVY incidence in potatoes to 42, 0, 68, and 55% of that in the controls ($p < 0.05$), and in three experiments Yalbin treatments reduced incidence to 0, 0, and 29% ($p < 0.05$). The efficiency of Loven and Yalbin was roughly comparable to that of Virol, which reduced PVY incidence to 0, 0, and 52% of the incidence in controls ($p < 0.05$), whereas, again, under the net no PVY infection was found (Table 2).

Effect of Loven, Yalbin, and Virol treatments on potato tuber weight, number, size, and shape. During harvest in spring 1980, a 1-m row was randomly sampled in the three replications of Loven-treated and control plots. A mean of 63 tubers per meter-row was found in the treated plots compared with a mean of 51 tubers for the controls, which is not significantly different. In autumn 1980, the middle row of each three-row replication was harvested separately. The results (Table 3) demonstrate a significant reduction of about 30% in total yield (weight) by each of the treatments and a further reduction (about 55%) by mixing Loven or Yalbin with Virol. The reduction is the consequence of the decrease in the number and weight of the large tubers (> 120 g). Weight and number of tubers between 30 and 120 g were not affected (Table 3). It should be noted that all the various treatments reduced ($p < 0.05$) the number of misshapen tubers: Loven to 3%, Yalbin to 1.8%, Virol to 5%, Loven plus Virol to 3.9%, and Yalbin plus Virol to 2.5% vs. 10.7% in the control. This may be related to the development in the control of larger tubers (Table 3), which are subject to a higher rate of deformation.

TABLE 4. Mean number of alatae of different aphid species captured per water trap in six pepper plots sprayed with Loven compared with the number trapped in six control plots

Species	Alatae (no.) Loven plots	Control plots
Aphis citricola van der Goot	3,271	7,521*[a]
Myzus persicae Sulzer	272	484*
A. gossypii Glover	235	146*
A. craccivora Koch	186	270
A. fabae Scopoli	56	169*
Unidentified	2,170	2,657
Total	6,190	11,247*

[a] Asterisks indicate significant differences between control and treated plots as analyzed by the Mann–Whitney U-test (17) at $p < 0.05$).

Effect of crop sprays with Loven, Yalbin, and Virol on alatae and apterae populations in the field. Loven or Yalbin treatment reduced the total number of aphids (Fig. 2) and the number of *M. persicae* (Fig. 3) that landed on spring and autumn potato crops to 30–40% of the number trapped in the control plots ($p < 0.05$). Virol sprays did not reduce the total number of trapped alatae, which may be related to the fact that the application of Virol did not change leaf reflectivity markedly (Fig. 1).

Loven sprays in pepper reduced *Aphis fabae* Scopoli to 33% of the number found in the controls, of *A. citricola* van der Goot to 42%, and of *M. persicae* to 56% (all different from control at $p < 0.05$). Loven sprays had no effect on the number of trapped *A. craccivora* Koch but increased the number of *A. gossypii* Glover to 161% ($p < 0.05$) (Table 4).

No differences were found in the number of apterae that developed in Loven-, Yalbin-, and Virol-treated plots (means of 11.4, 28.1, and 15.3 aphids per plant, respectively) compared with the untreated controls (mean of 7.2 aphids per plant).

Effects of Loven, Yalbin, and Virol on the procsss of virus acquisition or inoculation by the aphids. In addition to the effect

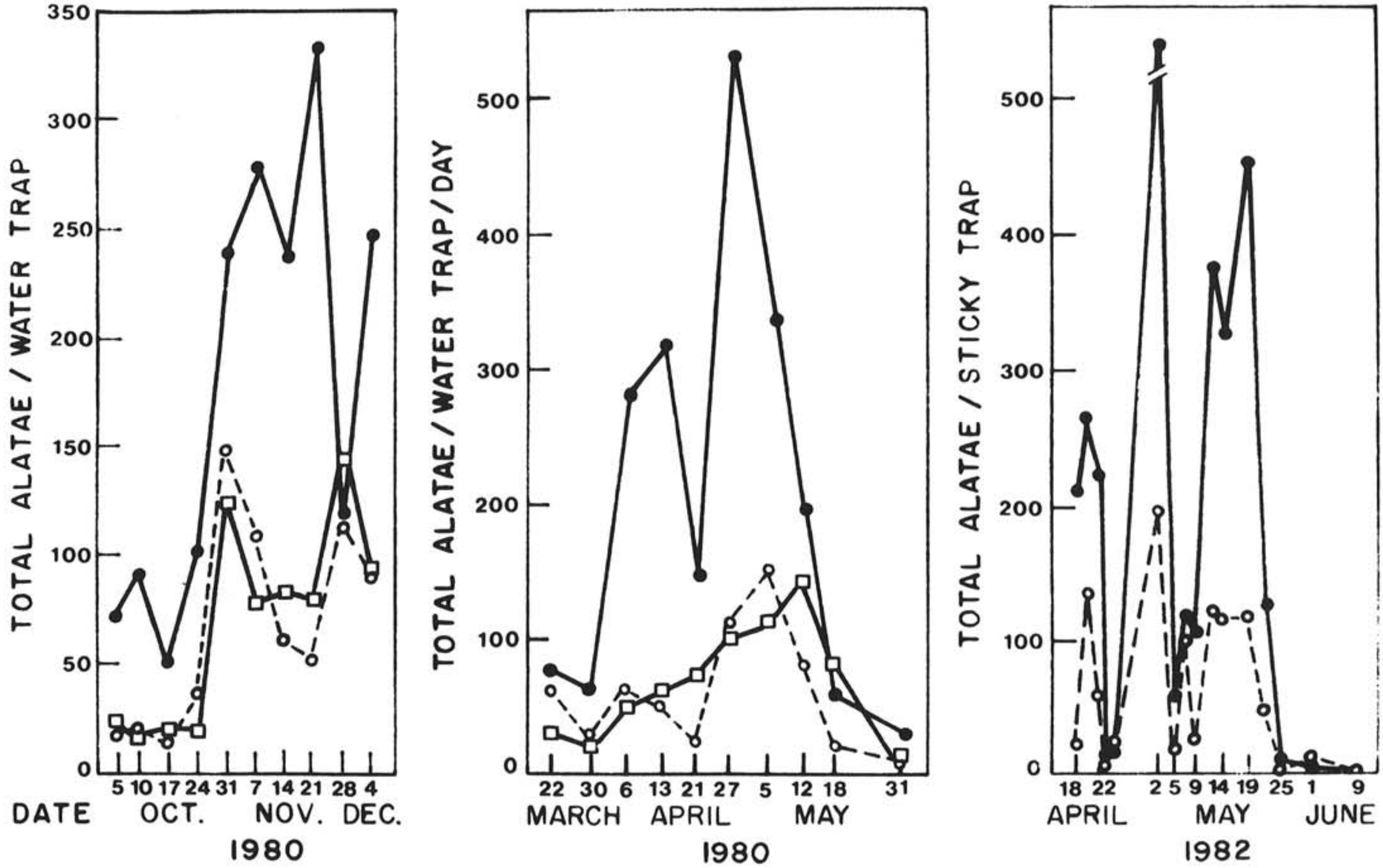

Fig. 2. Number of alatae trapped during spring and autumn, in whitewash-treated potatoes plots; Loven, (o—o) and Yalbin (□—□) in comparison with untreated controls (•—•).

on aphid landing, the presence of whitewash or oil on a plant leaf may interfere with the process of virus acquisition and/or inoculation by aphids. In five experiments, PLRV acquisition of aphids from half-leaves treated with Loven plus Dabak, Yalbin plus Dabak, Virol plus Dabak, or Dabak was not different from PLRV acquisition on control (untreated) half-leaves.

As for PLRV inoculation, Loven plus Dabak and Yalbin plus Dabak reduced the aphid inoculation rate in comparison with that of untreated controls, whereas no differences were found between Virol plus Dabak and Dabak itself to the controls (Table 5).

DISCUSSION

Weekly sprays with the reflective whitewash materials Loven and Yalbin reduced PLRV- and PVY-incidence in potato crops (Tables 1 and 2). In spite of the low virus incidences, the whitewash effect was consistent in different places and seasons for quite a number of years. A plausible reason might be the reduced landing of aphids on whitewash-treated plants probably because of their increased leaf reflectivity. The effect of these materials on aphid landing would probably depend on their reflective properties, on the ambient climatic conditions, and on the specific vector specimen involved. In our situation, the landing (total) of natural aphid populations in spring or in autumn was always reduced by Loven and Yalbin treatments. However, some aphid species, like *A. citricola*, were repelled to a greater degree than others, whereas *A. gossypii* was attracted to whitewash-sprayed plots. These results are similar to those obtained by Bar-Joseph and Fraenkel with kaolin sprays (1) and by Smith and Webb with reflective mulch (17). The selective repellency indicates that, for practical use of whitewash spray, one should take into account not only the climatic conditions but also the vector species involved in the crop and the area.

Another way by which whitewashes may decrease virus incidence is the possible interference of these materials while on

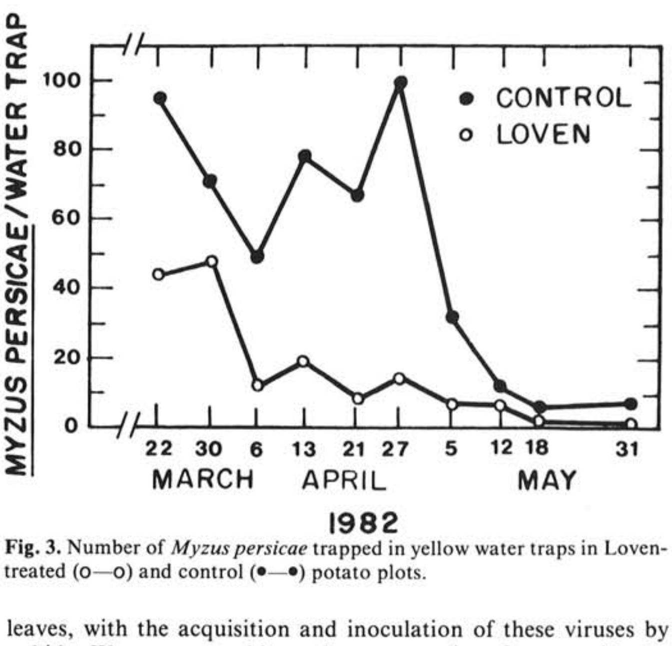

Fig. 3. Number of *Myzus persicae* trapped in yellow water traps in Loven-treated (o—o) and control (•—•) potato plots.

leaves, with the acquisition and inoculation of these viruses by aphids. We were not able to demonstrate interference with the acquisition process, but whitewash plus Dabak reduced aphid inoculation of PLRV compared with untreated controls, whereas oil (Virol) plus Dabak and Dabak treatments did not (Table 5). However, whitewash plus Dabak treatments did not differ from Dabak, so it is possible we have an additive effect of Dabak and whitewash. From the practical point of application this is of minor importance because whitewashes are to be mixed with Dabak anyway.

Loven and Yalbin treatments reduced PYV and PLRV in potatoes to about 30 and 40%, respectively. In areas where

TABLE 5. Effect of whitewash and Virol on inoculation of potato leaf roll virus (PLRV) by *Myzus persicae*[y]

	Percentage infection with PLRV				
Exp. no.	Love + Dabak	Yalbin + Dabak	Virol + Dabak	Dabak	Untreated
1	0(0/7)[z]	0(0/8)	11.1(1/9)	0(0/11)	12.5(1/8)
2	46.2(6/13)	0(0/14)	26.7(4/15)	57.2(8/14)	41.7(5/12)
3	35.9(14/39)	26.7(8/30)	33.3(12/36)	43.9(18/41)	40.2(17/40)
4	3.8(1/26)	7.4(2/27)	4.3(1/23)	15.4(4/26)	14.3(4/28)
5	18.8(3/16)	10.7(3/28)	8.3(2/24)	26.3(5/19)	22.7(5/22)
6	5.0(1/20)	0(0/18)	9.5(2/21)	7.4(2/27)	23.1(6/26)
7	6.1(2/33)	13.9(5/36)	8.8(3/34)	17.1(6/35)	12.9(4/31)
8	21.4(6/28)	75.0(21/28)	37.0(10/27)	75.0(21/28)	84.6(22/26)
9	20.0(2/10)	15.0(3/20)	11.5(3/26)	4.6(1/22)	12.5(3/24)
10	0(0/22)	16.0(4/25)	13.3(2/15)	14.3(3/21)	87.5(21/24)
11	8.3(2.24)	0(0/22)	36.8(7/19)	4.0(1/25)	72.0(18/25)
Total	15.5(37/328) b	18.0(46/256) b	19.0(47/249) ab	28.3(69/244) ab	39.8(106/266) a

[y] Apterae acquired PLRV from the same infected leaf and were allowed to inoculate treated and control *Datura stramonium* seedlings (two aphids per seedling).

[z] In parentheses: numerator, number of infected plants; denominator total number of plants. Data with the same letter not significantly different as analyzed by Duncan's multiple range test for $P<0.05$.

infection rates of potatoes are low, this treatment could enable production of seed potatoes. Net covers are more efficient, but it seems impossible to use this method on a large scale because of the high cost of labor and materials and technical problems involved. Whitewash is a cheap material and easy to apply. We had to spray weekly because of the overhead irrigation in our plots; however, in other systems of irrigation frequency of sprays would probably decrease.

The whitewash sprays done in these experiments decreased the total yield of potato tubers. This is in disagreement with previous reports that yields of sorghum (18), dryland cotton (4,15), melon (2), and artichoke (3) were increased after Yalbin treatments. In spite of the total weight decrease, the yield and the number of tubers between 30 and 120 g were not affected, and for seed purposes this is most important. Among other possibilities increasing whitewash reflectivity and understanding its effect on aphid behavior may improve the action of this treatment and work on these aspects is in progress.

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